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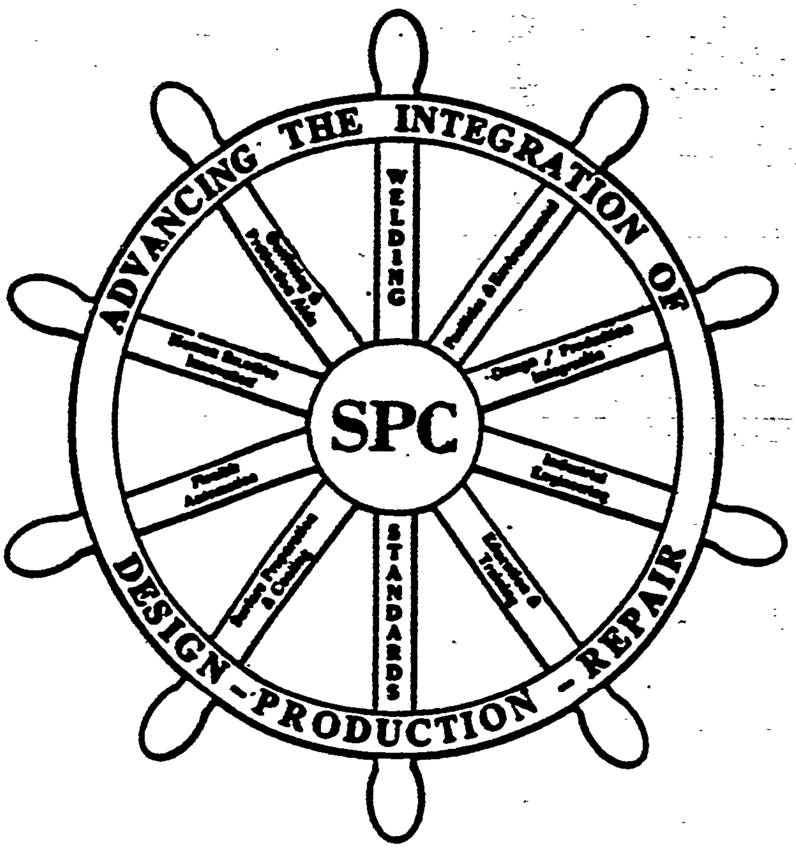

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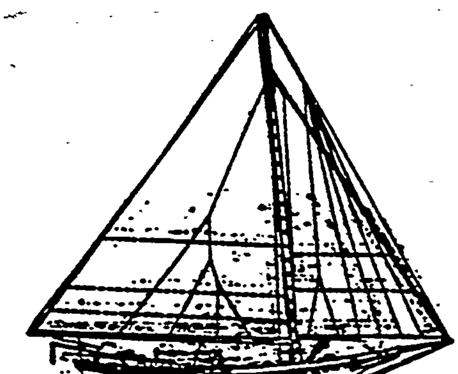

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Zone-Oriented Drawings for Life Cycle Management

No. 3B

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ABSTRACT

This paper presents the results of a study which was conducted to determine whether unit-oriented construction drawings, which are being developed and used by shipbuilders who are using modern zone-oriented, or modular, construction techniques, will satisfactorily substitute for system-oriented detailed arrangement drawings in the Navy's life cycle maintenance management process. The study concluded that modular construction drawings will provide the necessary data in a more usable format,. and thus are the preferred approach for the Navy's use. However, the study also identified several additionally needed features that are not now being provided in unit-oriented drawings, but which *must be* included in order to meet the needs of planning and maintenance activities during the operational life of a ship. A number of other observations about drawing use and maintenance are provided.

NOMENCLATURE

Because agreement on nomenclature is essential to communication, and because there seems to be no existing "standard" of terminology that crosses the boundaries of individual shipyards, the following descriptions are provided to orient the reader to the terminology that will be used In this paper:

"Zone-oriented" - This term is verv commonly used to refer to any ship construction approach which varies from the historically common system-oriented approach which has been used in US shipyards (except during wartime, when efficient production became the norm). However, because the word "zone" has come to be used in various places to to mean any part of a ship under consideration, including systems, that term will be used In this paper only in 1ts- most generic sense, i.e., to mean non-system-oriented.

"Modular. or Unit-oriented" - The essential difference that has been (re)introduced into shipbuilding practice is that the whole of any ship may be broken down into a number of basic construction units, each of which can be finished to as complete a condition as practicable, virtually independently of the others. Then, the units can be joined together to make up the whole, i.e., the ship. It is not uncommon for several units to be joined together into larger elements, which will be called "Blocks" in this document, before being joined together with other units or blocks at the final erection site. In all other construction industries this practice is called "modular construction". The term "modular construction" seems to better convey the basic approach used in this technique, and therefore it, and related *terms* such as "unit-oriented" or "block-oriented", will be used throughout this document to describe the more current approach to shipbuilding .

INTRODUCTION

Background

As shipbuilders have made the relatively sudden transition to the use of group technology in ship construction, they have found it desirable to make significant changes to the format and content of many of the drawings used in the construction process. These changes have been initiated with a single purpose in mind - namely, to present information needed by production personnel in the format which they, the immediate users of the drawings, find most useful. One guiding principle inherent in achieving this purpose is to avoid providing information that is not needed for doing the task at hand.

Before the transition back to modular construction techniques, ships were built by system, the largest and most extensive of which was the hull structure. Construction of the hull frequently was started as soon after contract award as possible, based more on the desire to meet a milestone for payment purposes and/or the need to keep the available structural construction personnel usefully employed than to ensure the most cost-effective construction scheduling. The installation of distributive systems, such as piping, ventilation and wiring, also was done by system. But since the development of the drawings for distributive systems was in part dependent on data from structural drawings, the distributive system drawings could not be finished until after the structural drawings. Thus, the structure was started first, and the distributive systems were installed after the hull construction was well advanced. The inefficiencies of this approach have been well documented elsewhere and will not be repeated here.

The significant point to be made is that those drawings whose purpose was to provide assembly and installation details in system-oriented shipbuilding programs were deliberately constrained to show information about a single system, because the workers who needed the information were working only by system.

Since the emphasis in modular construction is on the work content related to finishing a unit, the content of the assembly and installation drawings must relate to the unit. Most units contain parts of many systems, and seldom, if ever, all parts of any system. Thus, drawings which contain information about how to assemble and install the parts that make up a unit do not provide any information about any parts of any systems which are not In that unit. In other words, since the ship builders do not need system-oriented installation drawings, they are not producing such drawings. Consequently, system-oriented drawings are not available to the owner unless required by specific contractual language.

After ships are delivered to the owner, a whole new set of drawing users come into the picture. In the past, these users have received detailed drawings of each system, to use for whatever functions they perform. The procedures which they have developed for dealing with all of the elements of the life-cycle maintenance management process have been built, at least in part, around those system drawings. So the issue to be addressed is whether these users will be hurt or helped by having only the module-oriented drawings, which show how all the systems in some part of the ship are configured, as opposed to the system-oriented drawings, which show how one system is configured throughout the ship.

The initial reaction of most Individuals in the Navy who had not seen any drawings produced from modular shipbuilding projects, as might be expected, was that the Navy must continue to receive single system detailed *drawings*. However, many commercial and naval ships around the world have been built by foreign shipbuilders using modern shipbuilding techniques and have received only the drawings which naturally resulted from their building program. Because these shops have been operated satisfactorily with only those drawings, it was appropriate to study whether there were in fact, unique requirements of the U.S. Navy's life cycle management process that did demand detailed drawings of each Individual system.

Scope of Project

In addressing the issues presented above, the following basic questions need to be answered relative to the ship's drawings provided by the shipbuilder:

1. What do the Shipbuilder's drawings provide?
2. Who are the Owner's Users?
3. What are the Owner's Users' needs?
4. Do the Shipbuilder's drawings provide what the Owner's Users need?
5. If not, what changes are required?

Before addressing the answers to these questions, it is appropriate to consider the planned and actual approach to obtaining the answers.

Studv approach

The initial plan was to select two types *of* ship for analysis, each of which had two similar ship classes constructed recently; one class having been built using system-oriented methods and the other using modular construction techniques. The drawings prepared for the system-oriented ships and comparable drawings for the modular built ships would be presented to each of the user activities involved with that class of ship, for comparison and comment.

The ships originally targeted for the study were the AO-177 class and the TAO-187 class of oilers, both built by the same shipyard, but by different construction techniques, and the FFG-7 class, the early ships of which had been built using system- oriented methods, but the later ships of which repurteouly had benefited from application of group technology concepts.

The planned approach was to select one or more Ship Alteration packages being designed for the AO-177 class by its Planning Yard, Puget Sound Naval Shipyard, and identify which shipbuilder drawings, and specifically what data in those drawings, were used by the PSNSY designers for each phase of their effort. The next step would be to identify and obtain the drawings from the TAO-187 class which would contain the same type of data, and have the PSNSY engineers indicate whether it would have been easier or harder to have had such drawings available for their use.

The above steps were not able to be implemented as planned because of a number of factors. First, the TAO drawings were still in the process of being developed when the study was initiated. Thus, only a limited number of drawings were available for comparison. The Ship Alterations being worked on the A0 class were not particularly suitable to the analyses because a large number of the drawings being used were not the original drawings of the shipbuilder, but were drawings prepared by the Planning Yard for accomplishing prior system changes.

The choice of the FFG class had to be discarded because the changes in construction techniques were accomplished primarily by production planning docummentation without making new drawings to suit modularization of the process. A revised plan, to use the DDG-51 modular drawing5 for comparison with the FFG system drawings in the development of FFG Ship Alteration planning, could not be effected because the DDG-51 construction drawings were in the earliest stages of development and their ultimate configuration was still a matter of discussion at the shipbuilding yard.

As a result. the approach which was actually carried out involved discusfions with personnel at various naval activities, including Supervisors of Shipbuilding, Planning Yards and ships force. using typical A0 drawings and typical TAO drawings. of the personnel contacted, only those from PSNSY actually made the effort to visit SupShips New Orleans and Avondale Shipyard to see first hand the products which has been being generated there and accepted by the Supervisor for several years. The author has visited a number of private and public shipyards to ldentify the format and content of the drawings which they are now producing.

The findings and conclusions in this paper represent the author's reactions to all of these discussions, and are not intended to imply any agreement or disagreement by or with any of the personnel or activities with whom he had contact.

SHIPBUILDERS DRAWINGS

The Stages of the Detailed Design Phase

The Detailed Design Phase, which is carried out by or for the shipbuilder, consists of several separate stages. The drawings and other documents which are produced in each detailed design stage are quite different because they have different functions to perform. Reference (1) identifies four different stages, as follows:

1. Basic Design Stage
2. Functional Design Stage
3. Transition Design Stage
4. Working Drawings Stage

Stages 1. and 2. above are frequently classified elsewhere as a single stage. However, the above division recognizes the difference between the general space arrangement drawings and key structural drawings which must be defined immediately after contract award, (Basic Design Stage), and the system level drawings, produced during the Functional Design stage, for which the Basic Design Stage arrangement and structural drawings are prerequisites.

The primary impact of modular construction on the content of drawings is on the working drawings produced during stage 4, but all drawings have been impacted to some degree, as will be discussed in later paragraphs.

The Impact on Drawings of Different Types of System

The effect of modular construction techniques on content and format of drawings has not been the same for drawings of different types of systems. For the purposes of this discussion, it will be useful to categorize ship systems as either Structural, Mechanical, Piping or Electrical. In this classification scheme, Heating, Air Conditioning and Ventilation Systems (HVAC) are considered within Piping because of their functional similarities.

Electrical System wiring drawings have been modified the least, since most of the wiring installations are accomplished after the erection of the construction units into blocks or Into the hull, i.e., they are installed "On-Block" or "On-Board". Where it is found more effective to install electrical wiring systems during the unit outfitting stage, then the drawing information should be oriented to the unit(s) involved. Wireway drawings, for Instance, should be unit-oriented in order to allow installation of the wireways at the most appropriate point In construction. Normally this will be when the decks to which they will be attached are in the upside-down position. where all items which will ultimately be located on the overhead can be installed with the least manpower expenditure.

Many Mechanical systems drawings are unchanged for modular construction, because the information which they provide is normally more installation oriented, even in non-modular construction. If the equipment can be included in a machinery unit package, however, then the information will be provided in that installation drawing package.

The remaining discussion of drawing content will relate primarily to Structural and Piping Systems, because they are the most affected by modular construction techniques.

Basic Design Stage Drawings

General. In the United States, ship owners normally provide prospective shipbuilders with a number of drawings which, in addition to a set of shipbuilding specifications, describe the ship which they want to buy. However, since the contractual requirements usually make the shipbuilder responsible for delivering a ship which meets specified technical and performance requirements, the shipbuilder must check and verify every element of the design. Besides, it is often possible for the shipbuilder to make changes to design details which significantly decrease the cost of procurement and/or construction, without degrading the quality or the performance of the ultimate product. Thus, it is normal for the shipbuilder or his design agent go through the entire design development again, to verify the adequacy of the design and to develop the details of fabrication and installation which are not considered in the early design Phases.

The drawing products of this stage of design, then, are similar to those provided by the ship owner, but establish the baseline that the shipbuilder will follow in the remaining detailed design effort.

Space Arrangement Drawings. These drawings provide a description of where all the spaces in a ship are located, the purpose of each space, and the location of all major equipment within each space. This classification includes the General Arrangement plans, the Inboard and Outboard Profiles, and the Compartment and Access (C&A) drawings. It also includes the Arrangement drawings for major spaces such as Machinery Arrangements, Pilot House Arrangements, CIC Arrangements. etc. Such drawings identify the locations of major structural elements SUCh as decks, structural and non-structural bulkheads, and principal scantlings. These drawings do not need to be changed significantly in format or cantent for modular shipbuilding. In general, they are not system oriented, but provide the background for many other drawings and provide constraints which affect the layout of individual systems.

Key Structural Drawings. A number of structural drawings, such as the Midships Section Drawing and Shell Expansion, contain details of structural scantlings which define the adequacy of the structure to meet the loads imposed on the ship. These provide the basis for other drawings, which provide a description of how the transitions of structural details are to be accomplished. Because all other systems must be developed around the ship's structure, these drawings must be defined early in the detailed design effort.

Functional Design Stage Drawings

General. The drawings produced In this stage are in some ways the most important documents developed in the entire design process, because they must provide all of the information which will ensure that each system can and will carry out all of the system’s requirements, including all interactions with other systems. As such, they not only provide the shipbuilder with all of the information which must be used in the further development of fabrication and installation instructions, but also provide the owner and the regulatory bodies with sufficient information for their approval of the design. As will be emphasized later, they also provide the operators of the ship with the information necessary to understand the system's proper operation and to control the system's configuration during the operating life of the ship.

Note - For modular construction programs, these are the only system oriented drawings which are developed. In that sense they take on even more importance than they have had in the past.

Experience has shown that schematic representations of the system frequently are the most efficient ways of providing the required information. Thus, such drawings have generally become known as 'Diagrams". Very often, the schematic representation of the system is shown superimposed on a background that ldentifies the spaces through which the system passes. This is especially common with certain distributed systems, such as piping, for which the routing of the system must be considered, and for which elements, such as valve locations, which are vital to the proper design and/or operation of the system, must be defined.

Svstem Diagrams. For modular, as well as system-oriented construction, one diagram is produced for each individual system in the ship. For very extensive systems such as the Firemain system or the HVAC system, there may be many sheets in a system diagram. In practice, the term "diagram" is primarily applied to piping or HVAC system drawings. However, this term will be broadly applied herein to include certain structural and electrical/ electronic drawings, which, like piping diagrams, serve to provide all of the information necessary to ensure that the subject system will adequately accomplish every function for which the system exists. Electrical One-Line drawings, for instance, also provide the basic design data that control the overall system configuration and component sizing and do so in a schematic format.

In the structures area, drawings are developed for maJor areas of the ship, such as decks, bulkheads and frames, which may considered the principal systems of the ship's structure. In general, these structural drawings are not schematic, although it has become standard practice, in a number of other countries using advanced shipbuilding techniques, to use simplified representations of actual structure and thus to improve the productivity of the design process. For the purposes of the following discussion, these structural drawings will be considered under the term "diagram".

The information provided in Diagrams reflects the results of the calculations which have been made to determine required component sizing, material requirements and performance requirements. Data is provided in graphical, tabular or textual form, - whichever is the most effective techneque for presenting the information. Sence the diagram provides all of the data necessary for describing a systems basic functional requirements, including all information necessary to replace any component or piece of equipment in the system, it follows that a diagram is the only document creeded by anyone who need5 to know how the system is or should be designed, and what constraints must be satisfied when modification of the system is necessary .

Transition Design Phase Drawings

General. To fabricate system components and to install them properly requires precise, dimensional drawing data. The schematic drawings prepared in the Functional Design phase do not provide that kind of information. The "tool" that is used to take the data relating to individual systems from the diagrams produced in the Functional Design Stage, and to combine that data into a form that allows dimensioned Working Drawings to be produced in Stage 4, is the Composite Drawing.

Composite Drawings. Composite drawings also are arrangement drawings, but provide much more explicit detail. Their primary purpose is to locate, with dimensional accuracy, every portion of every system that exists in a volume of the ship. Composites have been commonly used for system-oriented shipbuilding, but in such cases their use usually has been limited to certain major, usually very congested, areas of the ship, such as machinery spaces, living areas, etc.

They are intended to preclude "interferences", the scourge of all shipbuilding programs. In most cases, composite drawings are too complicated to be used by anyone other than the people who prepare them. Thus, although they are essential to the shipyard's design configuration control process, they are not normally deliverables to a customer.

Conceptually, the content and format of composites are no different for modular-oriented programs than for system-oriented programs. However, in modular programs they are used more widely, extending throughout virtually every space in a ship. They are used for defining systems' details to a much finer level, for determining interfaces between construction units and other construction elements. They have, therefore, become of even greater importance to the shipyard.

With the advent of computer drafting programs with multiple 2D overlay capability or full 3D power, shipyards with sufficient computer capacity are developing composites in the computer. There is a maJor ongoing effort within the shipbuilding community to expand this capability to Include more than just graphics. The term "Product Model" is being used to describe this total description of the ship system, including material identification, etc., as well as configuration data.

Working Drawing Design Phase

General. Working drawings are produced primarily for the shipyard's production work force, to provide them with two different types of information. Both types of information may be included on a single drawing, but frequently, as will be assumed in this discussion, information relating to assembly and/or installation is provided on one drawing and fabrication data is provided on another. Thus, the first of these types of drawings will be identified In this document as Assembly Drawings, while the second type will be designated as Fabrication Drawings.

Assembly drawings are developed before Fabrication Drawings, because the system configuration must be established before the system can be broken up into the elements from which it will be built. Therefore, although Fabrication drawings are the first drawings to be directly used in the entire construction process, they are necessarily the last to be produced in the entire design process.

The construction process also requires the development of some type of work instructions, usually trade-oriented, which describe the precise work which is to be accomplished, how it is to be done and which drawing(s) and other documents are to be used for direction or guidance. These work instructions are developed normally within the Production Department, rather than by the Engineering Department. This study effort did not address the content of work instructions, but it is worthy of note that these should be work site oriented for modular construction.

Fabrication Drawings. Although the ship construction process is primarily an assembly process, each shipyard will manufacture as many of the parts to be assembled as they can efficiently produce. The fabrication drawings provide the data needed by shop personnel for manufacturing those portions of a system which the yard will build. Fabrication drawings are sometimes produced by subassembly, although it is more common for fabrication drawings to be developed by unit, with part numbering systems used to identify the work site where the part will be installed.

Many fabrication drawings have been produced by shop personnel in the past, and, being considered shop sketches rather than drawings, have not been given to the ship *owner* upon delivery.

However. it is becoming more common; particularly since the *use* of computers for drafting, for these drawings to be developed in the Engineering Department and to be listed in the Ship Drawing Index. AS such, they have ended up as deliverables. Thus, the Navy will receive more fabrication drawings as a result of shipbuilders using modular construction techniques.

Assembly Drawings. These drawings provide production personnel with all of the information needed for creating structural elements and for installing equipment and other parts of systems into the structure, including the dimensionally accurate location of each piece that is to be assembled. Although the function of these drawings is the same for system-oriented and modular construction practices, the drawing content is markedly different In each case. The differences will be discussed below.

Svstem-Oriented Working Drawings

During the working drawing phase of system-oriented shipbuilding, designers produced *a* separate detailed assembly drawing for each individual system on the ship. Similarly, fabrication drawings provided data relating to only one system on each drawing. Work lnstructions covered the installation of a single system throughout the ship.

Structural working drawings showed the exact dimensions of each piece *of* steel from which a deck or bulkhead was to be built and also showed how the parts were to be welded together to build the "system". Thus, one drawing could be used to determine how to cut out and weld up all the pieces which made up one structural "system" of a ship. Decks were considered as structural systems in this approach, as were Bulkheads, Frames, etc.

Piping configuration drawings showed the distances of the system ' s piping from major structure, such as the deck overhead or *a* bulkhead stiffener , for example. One serious drawback to these drawings was that they did not show the location of other piping systems. It was therefore necessary to look at several drawings to find the configuration details of different piping systems, even if they were, say, running parallel for many feet. Separate piping fabrication drawings gave construction details for each piece used In making up a single system, throughout the ship.

For' electrical systems, wireway routings were developed from the composites and shown deck by deck. The wireways were then installed inside the ship after spaces were all closed in.

Modular Working Drawings

General. A shipyard using modular construction techniques cannot effectively make use of the type of system-oriented assembly and fabrication drawings described above. Instead, drawings must relate to the units, sub-units or blocks of units in which the system elements are to be installed. Unfortunately, since at this point in time virtually every shipyard is developing their- own, individualized set of drawing types, which they consider will best enhance their producibility during the modular construction process, . it is not possible to generalize on the format and content of the drawings being developed. However, the differences relate primarily to the size of assembly which is addressed in the documentation and to the nomenclature used to describe the processes involved. Some assembly drawings address individual units, some address each sub-unit, while some address blocks of several units.

A shipyard may use each of these in various combinations for different system types, i.e., structural drawings showing fabrication and assembly by sub-unit, plus structural drawings showing assembly of sub-units into units and fabrication details of any structural elements which may be added during that effort; piping assembly drawings showing several units in one drawing, with separate fabrication drawing packages for each unit showing the pipe details for all the piping svstems In that unit; and wireway assembly drawings by block. of several ad-Joining units.

Unit-oriented drawings. Unit-oriented structural drawings define the configuration of each of the structural parts from which a unit will be assembled , provide all of the welding information, and all of the dimensional details which must be used by the construction workers to construct the unit. Ideally, these drawings identify every hole which must be cut for any piping or electrical system penetration 6.5 well as all structural cutouts, so that these all can be accomplished during the original fabrication of the structure .

It is common practice in many yards to provide additional drawings for each stage of subassembly of each unit. particularly If the subassemblies a1.e to be constructed at different sites and assembled at another location or If there wi11 be outfitting of the sct.assemblies before they are joined with other subassemblies.

Unit-oriented piping system drawings show all of the elements of every piping system which are to be installed in one unit. Thus , each such drawing is a mini-composite of all the piping system5 in one unit. Part fabrication drawings provide, in one drawing, information pertaining to all parts of all of the systems to be installed in one unit.

Svstem Drawings bv Unit. At one shipyard, for one program, a separate drawing was produced for fabrication and assembly of the part5 of each piping system installed in each unit. This was driven by someone's perception that it was necessary to maintain the purity of the SWBS.number in the drawing number. This approach represents the worst of all worlds, in that it provides neither a complete system description nor a complete unit description, and therefore doesn't serve the real or perceived needs of any user ! This extremely non-productive approach is no longer being followed and is mentioned here only in the hope that it will serve to ensure that no shipbuilder will ever again follow it.

Block-oriented Drawings. Some shipyards have found it desirable to show all of the piping in several adjoining units in a single assembly drawing, *even* if the piping will be installed in each unit at a different place or time. This has not resulted in any confusion for production personnel during the assembly process, since the personnel at a given work site are provided with only the pieces which are to be assembled at that work site, and are given work instructions pertaining only to the work to done at their work site. It has not been found necessary in all cases to provide separate drawings for each work site.

Sub-unit-oriented Drawings. Because most units are built up of smaller sub-units, and in many cases sub-units are outfitted before being joined with other sub-units into units, it is very common for separate assembly drawings to be developed to describe the work to be done on each sub-unit and/or at each work site. At some shipyards, these are produced in addition to the drawings which provide information at the unit or block level.

However, at least one shipyard is presently planning to prepare all drawings by system type at the subassembly level, and to combine all of the sheets for all of the unit's subassemblies into a single unit booklet. Although this would appear to provide all of the information needed in the future for any part of any system of that unit. it does so in such a fractionated way that it will be very inefficient for the life-cycle process.

Machinery Unit Package Drawings

Most of the units into which a ship is broken down for the application of modular construction techniques are primarily structural units, to which portions of other systems *are* installed during the construction of the unit. However, it is very cost-effective to assemble several items of equipment onto a common foundation in the shop and then move all of this equipment as a complete entity into its final location onto a structural unit or on board. This entity can include all of the gages, tubing, and other instrumentation necessary to operate or control the equipment locally. It can be hydrostatically tested in advance. This approach has many been applied in system-oriented construction in a very limited way, such as for preassembled piping runs for congested spaces, but is being applied much more broadly in modular construction.

Separate drawings are produced for these machinery package units. It is common for these drawings to include structural and system routing details on separate sheets of the same numbered drawing. Thus all information needed to build or modify the assembly of any part of the equipment in that package is available in that drawing.

USERS AND THEIR NEEDS

Introduction

One element of the study effort was to determine what information is actually needed at each stage of the post shipbuilding process, an obvious prerequisite to a decision about the adequacy of the builder's products to meet those needs. This involved, first, identifying the users and then assessing the information needs of each of the users. In the U.S. Navy, as well as in any other Operator's organization, there is a defined structure for maintaining and operating the ships. Since that of the USN is more complex than most commercial operators, this study has concentrated on the USN structure. However, the findings are applicable to any operator.

Users

Ship's Force - The personnel who operate and maintain a ship on a daily basis are an important source of information about the need for modifications to existing system installations in order to improve the ship's performance or simplify its maintenance. Since the standardization of ships and systems within classes is a high priority in the USN because of crew training and maintenance planning considerations, system configuration changes are not intended to be accomplished by ships force personnel without authorization. However, if the ship's force are able to accomplish the changes within their own resources, it is not unknown for them to do so, with or without the knowledge and consent of others outside the ship who have responsibility for configuration control.

Operating Commanders/NAUSEA Headquarters - These organizations ultimately are responsible for approval of proposed changes to ships existing systems and configurations. They frequently initiate the process, but more of ten approve further development of changes that are proposed by others.

Planning Yard - One shipyard, usually a public (US Naval) shipyard, is assigned the responsibility for maintaining configuration control of a ship class. 'This yard is also responsible for developing any approved system configuration changes to a Class of existing ships. The Planning Yard responsibility always includes the development of the drawings which are to be used by the Installing Activity, I.e., that shipyard which is ultimately authorized to accomplish the work. Most often, the Planning Yard is not the Installing Activity.

Supervisors of Shipbuilding - The USN has established several offices in different parts of the country, each of which is responsible for the contract administration of assigned shipbuilding and/or overhaul programs. Their responsibilities for shipbuilding programs include drawing review, occasionally drawing approval, oversight of the procurement of material, as well as quality assurance and financial management functions. Their responsibilities for overhaul and repair work include putting together packages of prospective work, distribution of these data for bidding purposes, selecting the yard which will accomplish the work, and oversight of the work being carried out by that yard.

Installing Activitv - The shipyard, either public or private, which is assigned the task of making specific changes to a ship's systems.

Users' Needs

Ship's Force

Operation. Operation of the ship by the ship's force does not require use of the construction drawings developed by a shipbuilder. However, Equipment drawings, Technical Manuals and other documentation which the shipbuilder obtains from the equipment supplier are of more direct use to the ship's force. These documents also are used by the shipyard personnel when installing, checking out and operating the ship's equipment during construction, but they are not developed by the shipyard. There is no change needed or desired in the format or content of this type of documentation.

There are still other documents, such as Damage Control documentation, Maintenance Requirement documents, Ships Instruction Books, etc., which may be developed by the shipyard, but these are not used by the shipbuilder for his own purposes during construction, and thus are not being addressed herein.

Maintenance. Maintenance of a ship, on the other hand, may require some of the shipbuilder's documents, as well as some of the other documentation such as Equipment Technical Manuals addressed above. Maintenance problems are usually equipment oriented, rather than system oriented, and normally are local in nature. Therefore the ship's force relies much more heavily on the equipment oriented documentation than on the shipbuilder's drawings. Since most of the problems which occur during operation relate to equipment, and since the cause of most of them is obvious, it is not surprising that discussions with shipboard engineering personnel revealed that most of them never use the drawings which they carry on board. They indicated that, with minor exceptions, the only time they went to the drawing file was to satisfy inspection requirements or to provide drawings to visitors to the ship, such as to shipyard personnel who come aboard to do shipchecks for various purposes. The minor exceptions include the need to use certain electrical drawings when checking electrical problems and occasional use of diagrams for familiarization purposes.

Despite the response described above, it is more reasonable to believe that shipboard personnel actually do need to have copies of every system diagram on board, since these drawings provide the only complete and concise description of how the system is supposed to be designed and of its Intended operational parameters. These drawings also contain the information the ships forces need for ordering replacement items. Whenever they need to make minor modifications to a system, they can use the same guidance (USN Ship Specifications and General Specifications, ABS Rules, Coast Guard Regulations, etc.) that was available to the ship's designers.

It is also to be expected that a Fabrication drawing would occasionally be useful for manufacturing a replacement item such as a length of pipe, ventilation duct, *etc. However,* since these types of items usually can be made by templating existing parts, the availability of fabrication drawings is by no means a necessity.

Since the ship's force have the as-built ship as a full scale model, it is hard to imagine any need which they might have for detailed arrangement drawings, except in the case of major damage due to collision or battle damage. However, even then, the emergency on-site repairs which would be made by the ships force or by other repair activities, would constitute emergency repairs, for which the detailed drawing information would be very useful , but not essential.

Planning Yard

General. Planning Yards have the greatest functional need for the shipbuilder's drawings, since they must provide similar drawings to other shipyards for making modifications to the ships' systems.

Planning. The Planning Yard's efforts normally start with receipt of a Ship Alteration Record (SAR), which describes what changes are to be made to a system and identifies what equipment will be provided by the authorizing activity, and with authorization to develop the drawings and other data which will be needed by the Installing Activity to accomplish the work. The Planning Yard efforts require the availability of system diagrams of all systems impacted in any way, for evaluation of the impact on siring of equipment or system components and for ease in identifying system material requirements.

Shipcheck. The yard then, using the Ship's Drawing Index as a guide for identifying the drawings needed, gathers together all of the ship's Assembly drawings which relate to the systems involved in the Shipalt. They take these documents to the ship and use them to check whether the actual inStallatiOn iS as shown on those drawings. They also verify or determine and document how the revised installation will be configured by either marking up the as-built drawings or developing sketches onboard.

Design Development. Following the shipcheck, the Planning Yard personnel develop all of the drawings that will be required by the installing shipyard for accomplishing the work involved. This may involve preparation of drawings which describe what parts of an existing installed system are to be ripped out, using the assembly drawing, as well as drawings which describe the new installation. Ripout drawings can be made quickly and easily by tracing existing assembly drawings, in the manual mode. The modifications will be even easier to produce for drawings which exist in computer files. Fabrication drawings would provide much useful information to Planning Yard personnel if available.

Supervisors of Shipbuilding

Shipbuilding. Since the primary time frame of interest in this study is the post-shipbuilding life cycle of the ship, the Supervisors' need for drawings during shipbuilding is noted only in passing. Obvious&y, all drawings produced by the shipbuilder are needed by SupShips during the building phase.

Overhaul. In order to properly carry out their responsibilities for overhauls, the SupShips organizations would need only the drawings prepared by the Planning Yard if there never were any question of their accuracy. However, despite the fact that the Planning Yard is responsible for the technical adequacy of the drawings, the Supervisor must have both the System Diagrams and the Assembly drawings of the as-built ship in order to properly and expeditiously respond to technical questions which arise.

Installing Activitv

Installation. The installing activity should need only the drawings provided with the government's contract to do the work, thus it does not have any functional need for copies of the original shipbuiIder's drawings In order to accomplish the changes to the systems' configuration.

EVALUATION

Introduction

It has been determined in the foregoing that, with the exception of manually developed composite drawings, all of the different types of drawings developed by shipbuilders during the Detailed Design Phase are useful, in varying degrees, to each of the USN organizations which have life-cycle maintenance responsibilities.

In the past there has been no need for users to receive copies of the composite drawings, which are used by the shipyard for integrating all detailed system arrangements. However, with the advent of computer drafting, it ultimately will be helpful for the Planning Yard to have the computer tapes with the composite data.

Nevertheless, it was found during the study that certain changes must be made to these drawings In order to make them better able to serve the life-cycle users' needs, even though there has been no need for the shipbuilders to significantly modify the content or format of the system diagrams for their own purposes in effectively converting to modular construction techniques.

The working drawings represent the area of greatest concern or interest, primarilv because their format and *content* have changed so greatly from those with which users have experience, but secondarily because there *are* not yet any standardized techniques for providing the required data.

Each type of drawing will be discussed separately, after which a serles of issues of general applicability to each type of drawing will be addressed.

System Diagrams

General. All of the information that has been provided by shipyards in system diagrams for system-oriented construction remains essential for modular construction. However, what has not been recognized, in general, is that additional information must be provided on the diagrams whenever all working drawings are developed to suit modular construction, i-e., to address units instead of systems. If It is necessary to call out these requirements in contract language as part of the shipbuilding specifications, then it should be done.

Correlation with Working Drawings. As has been covered in detail elsewhere, working drawings for modular construction seldom, if ever, show a complete system in one drawing. Major systems will appear in many separate block, unit or sub-unit drawings, instead of a single drawing. In the past, when it was necessary to go from the system diagram to the working drawing which covered a part of the system about which one needed additional information, there was only one drawing to find and look at. Even if the diagram did not include the number of the corresponding working drawing in its reference list, the working drawing's title would include the system name and its number would include the same SWBS number as the diagram, making it simple to quickly locate the correct number in the Ship's Drawing Index (SDI). This is not possible when, as in modular construction, working drawings are not system oriented.

During the course of this study, the author has not seen any system diagram which has provided any technique for leading one to the related working drawing(s). The only technique currently available for finding the drawing which contains the details of interest is to go through the following steps:

a. Find a drawing which identifies the ship's unit breakdown.
b. Identify the unit number(5) most likely to include the volume of the ship in which the pertinent part of the system is located.
C. Search through the SD1 to find the working drawing which has that unit number in its title or in its own drawing number. This assumes that the working drawing numbering system or the drawing title will include the unit number. Otherwise, search through the SDI to find some other clue to identify the desired drawing, such as the compartment type.

This technique is obviously very inefficient. Of several possible solutions to this as yet generally unrecognized problem, the simplest would be to provide a matrix table in the diagram, to correlate each area of the system diagram to the number of the working drawing which contains the detailed information about that part of the system. It would be very helpful, but inexpensive, to show the location of unit boundaries on the diagram, as well.

Correlation with Compartmentation. Once a ship is built, the easiest way to describe the location of a piece of equipment or of any part of a system is by use of the compartment number in which it is to be found. Therefore, the compartment numbers should be shown on diagrams. The most effective way to do this will vary, depending on the extent of the system, but in most cases it can easily be accomplished by using a schematic representation of the compartmentation as a background for the system routing shown on the diagram and labeling each compartment by number. Labeling the compartment by name would even further enhance the ease with which the diagram can be used.

Assembly Drawings

General. The major user of the Assembly drawings during the life cycle of a ship is the Planning Yard. Their primary use of these drawings is to verify, by shipcheck, that the data on the drawings is accurate, so that the designers can use that data with confidence when developing their new drawings. In the manual drawing mode, the original drawings sometimes are used for tracing unchanged portions of the system.

Numbering and Titling. As mentioned earlier, In order for the working drawings to be most useful to users. they must be identified in such a way that they can easily be related to the portion of the ship to which they apply. Thus, the system used for the titling and numbering of working drawings must allow easy recognition of the unit, block or compartment(s) to which the drawing relates.

Modular vs System Orientation. Because these drawings are used by the Planning Yard for shipchecking of the existing layout of ships' systems and for planning how to modify the existing layout to most effectively accomplish the purposes of proposed system changes, it is obvious that the unit- or block-oriented assembly drawings, which provide a composite picture of all the systems in a given volume of the ship, will be much more useful to the Planning Yard than the single system drawings which they have had to use in the past. This will be true even when it is necessary to look at the whole system, which may involve looking at several unit-oriented drawings. When using system-oriented data, it is always necessary to look at several drawings, but even then the interrelationships between systems are much more difficult to discern.

Area Coverage. To be of greatest use to the Planning Yard, assembly drawings should show data relating to an area of the ship which has some functional significance, such as at least one level of a machinery space. This will usually require that more than one unit be included in the drawing .

at the other end of the spectrum are Assembly drawings which show only the data relating to the construction and outfitting of each individual sub-unit. While such drawings may be considered ideal for the use of the building yard, they will not provide enough data to be useful to the Planning Yard. It will be necessary for the Planning Yard engineer to review tOp many drawings in order to obtain the information concerning a meaningful volume of the ship.

Since some shipyards have bypassed the block or unit level of drawing and are concentrating on producing only the sub-unit level for their own use, it is possible that shipbuilding contract language will have to address this issue. The two aspects to be considered are:

a) whether the shipyard needs to generate these block or unit level drawings (in addition to at least some sub-unit level drawings) for their *own* productivity , and
b) whether the *users* need this level of drawing to most effectively carry out their responsibilities.

Since it has been evaluated in this study that the answer about the betond aspect is "yes", the first aspect must be addressed. At this time is in only possible to state that at least. one of the yards which converted completely to modular construction techniques has found the block/unit level of drawing to be sufficient for all work but structural work.

Specifically, in the building of the TAO program, most piping assembly drawings covered a block of several units and were used directly at each construction site by the shipyard production workers. Fabrication drawings for piping, on the other hand, were developed unit by unit. Structural drawings, containing both fabrication and assembly data were developed by unit and then used by mold-loft personnel to develop additional drawings at the sub-unit level. The sub-unit level structural drawings were the primary drawings used by production personnel during the construction process, but the unit-level drawings produced by the engineering department were continually available for reference. This combination was considered by that shipyard to be very cost effective, and has continued to be used in their subsequent shipbuilding programs.

It is also of significance that one Planning Yard has taken the trouble to visit this shipbuilder and review the content of the drawings being produced, and has concluded that the drawings as being generated will satisfy their needs, with the exception of certain of the matters being addressed in this report.

‘Other shipbuilders are pursuing different courses. It may be coincidental, but the shipyards which are developing the most detailed levels of drawings are the ones with the greatest computer drafting capabilities. It is possible that some drawing practices are being driven more by a desire to make maximum use of the computer drafting capabilities that exist than by the results of a demonstrated cost-benefit analysis. The results from these building programs, when completed, will be of great interest to the industry.

Readability. Many of the modular-oriented assembly drawings which have been developed to date are SIGNIFICANTLY harder to read than single system drawings, which can be difficult enough to follow, anyway. Al though experience with the terminology and content of modular drawings makes their use less difficult, and obviously the shipyards themselves are using them successfully, an improvement in readability is a most desirable goal. Systems which traverse Large areas of a drawing need to be Identified frequently enough that a user does not have to search all over a sheet to find what the lines represent. Scales must be large enough that all of the identifiers and dimensions on the sheet can be read without confusion. Common sense will ultimately prevail . but early attention to this need will be helpful to all concerned.

Fabrication Drawings

These drawings have been determined by Planning Yard personnel to be extremely useful for their efforts to provide information to Installing Activities for replacing existing systems. Fabrication details in the past of ten were left for the shop planners to develop, but are now a recognized part of the Design Engineering effort. As such, they are included In the Design Drawing Schedule and included as deliverables to the government at the end of the contract.

While not exactly a life-cycle issue, it is notable that these fabrication details, being deliverables to the government, can be made available by the government to the shipyards which produce follow ships of the class, and in the author’s opinion should be. Whether they should be made available during the bidding process is. arguable, but seemingly it would be In the government’s best interest to provide these drawings as part of the follow ship contract award, at least, so that the follow shipbuilder would not have to expend the effort to replicate them unless he chose to do so because he had a more cost effective fabrication technique available. Unfortunately, the specter of Claims against the government, when documents provided by them are found to have any problems, is an overriding deterrent from doing some otherwise intelligent things. There are a number of fairly obvious way5 of overcoming this problem, but it will require a greater desire to do so on both sides of the contracting table.

General

User Capabilities. Another important consideration in the evaluation of drawing format has to do with the customers’ ability to use the data as developed. With many drawings being developed on computer drafting systems, it is frequently assumed that the shipbuilders will only have to turn over the data bases to the customer and the customer will be able to generate drawings in any format and with any content that the customer desires. It must be recognized that although many Planning Yards and other USN activities have excellent computer facilities, it is a fact that most lag well behind the private shipyards in the number of terminals available to design personnel.

Further, despite some excellent continuing efforts, the commonality of the systems which are currently available in various shipyards is by no means adequate, nor is there adequate ability to transfer and use data generated in different systems. Until a number of serious problems are solved, it will be absolutely necessary for the customer to require delivery of hard copies and reproducible masters of drawings that are. in the format and that have the content identified herein as being most useful.

Drawing Maintenance. Discussions with Navy personnel, aboard ship and at the Planning Yard, have identified that the ships drawings are not being adequately maintained in an up-to-date status.

Drawings and other documents which are identified as Selected Records Data are supposed to maintained current at all times. Specifically, within 90 days after any availability, all SRD is to be updated to reflect all changes made to the ship's systems' configuration since the last update, i.e., to include all authorized and unauthorized changes which have been made since the last update.

The first problem is that this policy is very poorly executed. Most ships are operating with most of their SRD at least one year out of date, with the documents to be changed sitting in some design office awaiting additional funds to complete the effort.

The second problem is that, except in submarines, most system diagrams are not included as SRD . Those portions of diagrams and other documents which appear as enclosures in Technical Manuals or Operating Manuals will be updated, since those documents are included as SRD, but the actual drawings will not.

The situation is exacerbated by the fact that there is no requirement for the Planning Yard to update the Assembly drawings, which are the only drawings which provide a true, dimensionalized description of the ship's configuration. The drawings produced by the Planning Yard provide the installing activity with just the information needed to rip out any portions of existing systems that are to be replaced and to install the replacement parts. Fabrication data may be left for the installing activity to develop. Thus, after more than one change to any existing system, there may be three or more drawings which have to be reviewed together in order to obtain an accurate description of the current configuration of the system.

It is hardly surprising, under the circumstances, that the ships force personnel don't feel that they have much need of drawings of the ship or its systems (or for those who are responsible for providing this service to them). The ship as it exists is the only description of its configuration that they feel they need. Indeed, it is probably the only correct description that exists.

If there is any need for any of the drawings developed by the shipbuilder to be maintained in a current state of accuracy, (and there most certainly is), the priority should be given to system diagrams, space arrangement drawings and then assembly drawings. When computer composites exist and can be updated, then their priority would come after diagrams and before space arrangements, and their updating would eliminate the need to update assembly drawings.

Format Issues. One significant item concerning drawing format emerged during discussions with Puget Sound Naval Shipyard personnel. The introduction of computers into the design process has led to the typing of many portions of some drawings, such as General Notes or Material List information, at a terminal. The problem occurs when these sheets are printed out on paper of a different size than the rest of the drawing. This is not unique to drawings prepared for modular construction, because this problem already exists. The problem comes when someone attempts to obtain a copy of the drawing. If part of a drawing is prepared on large sheets, which are rolled up for storage, say in the Technical Library, and other part5 are prepared in booklet form using 8 l/2 x 21 paper, the Technical Library will very likely end up stowing the booklet portion in a location separate from the rolled storage. Then, when someone orders the drawing, they may not get all of it. The solution that has been used by one shipyard is to develop the material information as a separate "drawing", with a unique title and drawing number. The essential element of any solution is that all. sheets of any drawing be of identical size.

CONCLUSIONS

The conclusions of this study, based on the evaluations described in the preceding chapters, are as follows:

The Space Arrangement drawings and System Diagrams are needed by all activities involved with ship maintenance planning and configuration control.

The importance of System Diagrams needs to be emphasized. Updated versions of these documents must be available to the ship's force and to all involved maintenance activities at all times. The format of these drawings reeds to relate directly to both the final ship compartmentation and the construction unit breakdown. The drawing content must include a matrix table or other technique for uniquely identifying the assembly and fabrication drawings which provide the details of how each part of the system is made and/or installed.

Composite drawings are needed only by the Planning Yard, and then only if they are in the form of computer data, suitable for use in producing copies of drawings by the Navy personnel.

The primary user of Arrangement and Fabrication drawings is the Planning Yard, but the ship's force also need to have copies available for potential use in emergency situations. Supervisors of Shipbuilding also will need these drawings for ships whose overhauls they are supervising.

There is no need for the Navy to receive detailed arrangement drawings of individual piping, structural or electrical systems, as long as they receive arrangement drawings which show the arrangement of all of each type of system in a reasonably large area of the ship. The modular type of drawing will actually meet their life-cycle management needs better than the individual system drawings.

The page size of all sheets of each uniquely numbered drawing must be the same.

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Additional copies of this report can be obtained from the
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